United States Patent [19]

Bateman et al.

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[45] **Date of Patent: Aug. 7, 1990**

[54] **SHAPING OF AUTOMATIC AUDIO CROSSFADE**

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[73] Assignee: **The Grass Valley Group, Inc.**, Nevada City, Calif.

[21] Appl. No.: **263,293**

[22] Filed: **Oct. 27, 1988**

[51] **Int. Cl.**[5] **H03G 3/00**
[52] **U.S. Cl.** **381/107**; 381/119
[58] **Field of Search** 381/119, 117, 107, 1, 381/627, 702; 84/1.27

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Primary Examiner—Forester W. Isen
Attorney, Agent, or Firm—Francis I. Gray

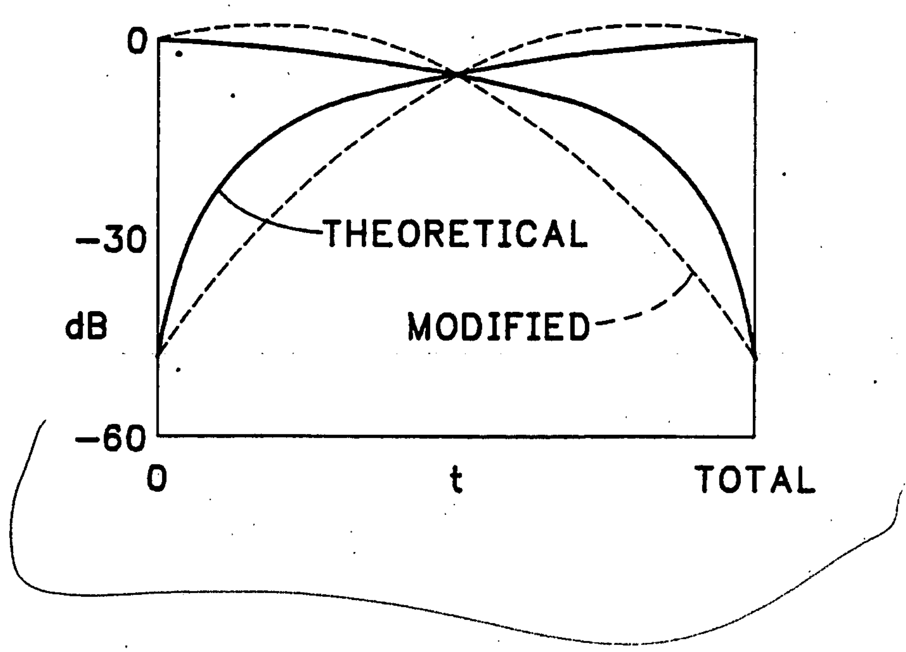
[57] **ABSTRACT**

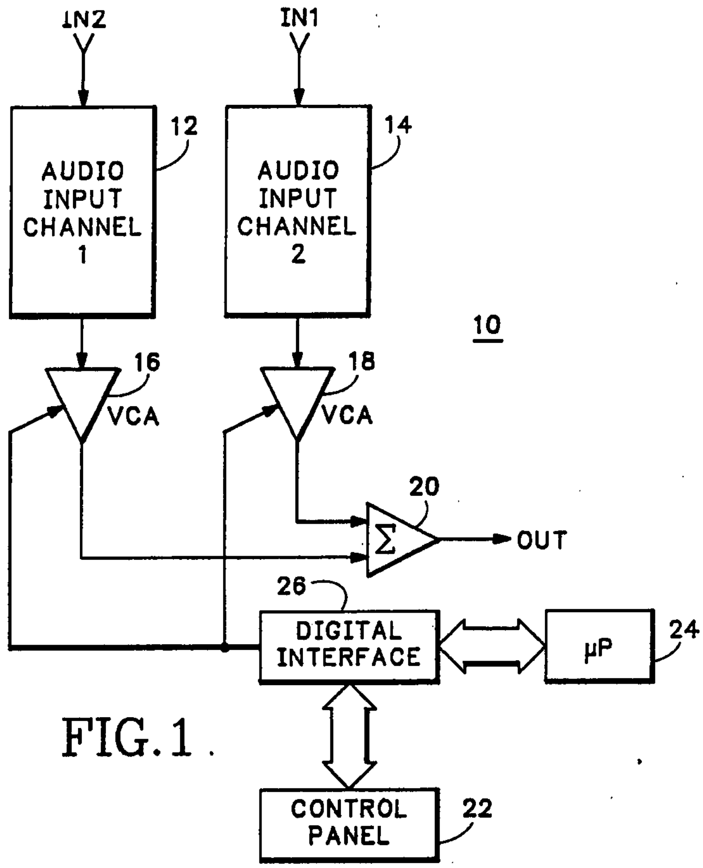
Shaping of automatic audio crossfade is accomplished by adding a shaping function to the theoretical logarithmic crossfade function to decrease the rate of gain change at the limit of audibility. The gain change at each sample time within a crossfade interval is computed as a logarithmic function of the fractional part of the crossfade interval completed and the gain differential between the sources. The shaping function may be in the form of a cosine function that can be accessed with a look-up table that is added to the fractional part of the crossfade interval so that the gain change is expressed by:

ti $G_{delta}=20*\log\{(k-s(k))*10^{(G_1-G_2)/10}\}$

where S(k) is the shaping function, k is the fractional part complete and G_1-G_2 is the gain differential between sources. The gain change is added to the current gain for the particular audio source and applied to a variable gain element for that source. The outputs of the variable gain elements are summed to produce the resulting output audio mix.

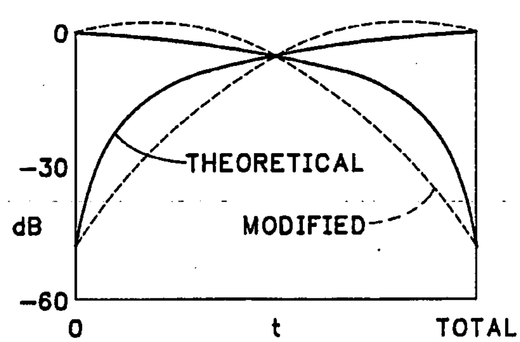
5 Claims, 2 Drawing Sheets





IN2
IN1
AUDIO INPUT CHANNEL 1
12
AUDIO INPUT CHANNEL 2
14
10
16
VCA
18
VCA
20
OUT
26
DIGITAL INTERFACE
μP
24
CONTROL PANEL
22

FIG. 1



0
-30
dB
-60
THEORETICAL
MODIFIED
0
t
TOTAL

FIG. 3

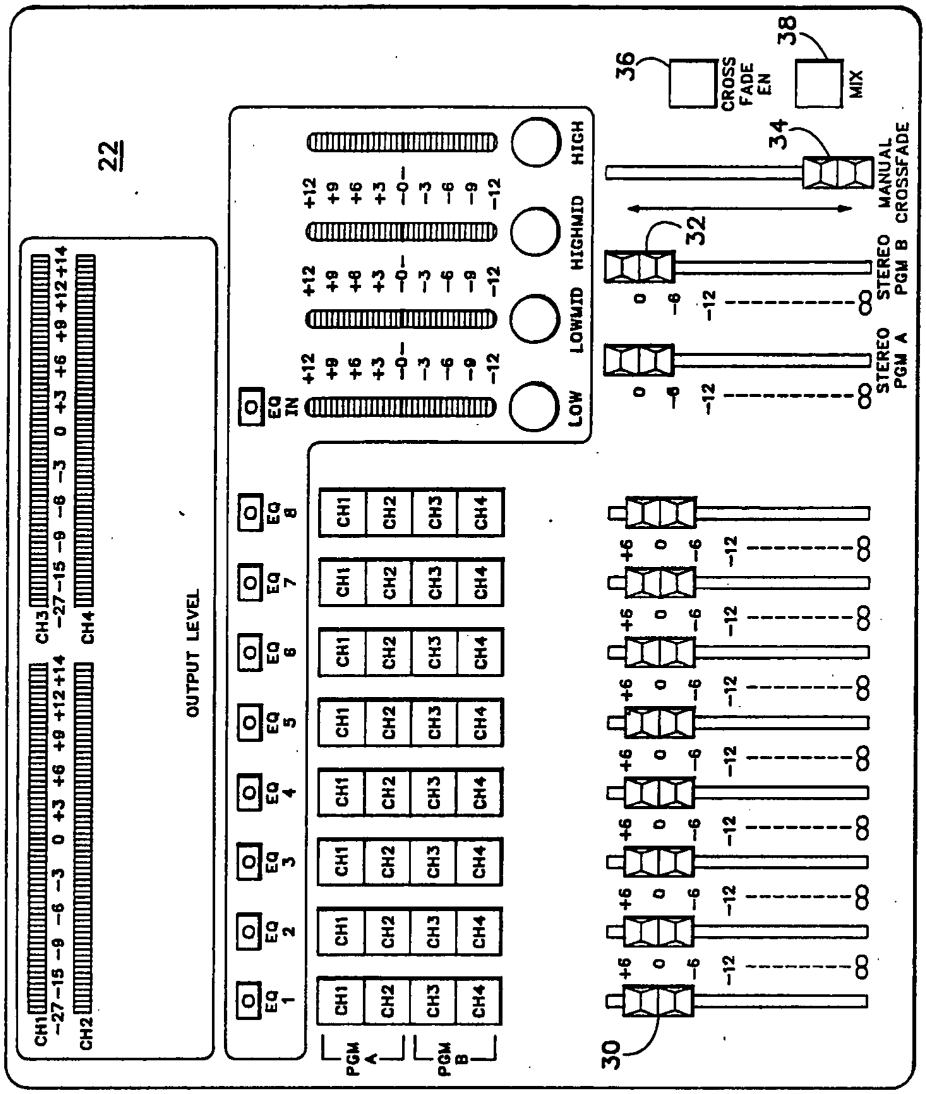

22
OUTPUT LEVEL
CH1
CH2
CH3
CH4
EQ IN
LOW
LOWMID
HIGHMID
HIGH
PGM A
PGM B
STEREO PGM A
STEREO PGM B
MANUAL CROSSFADE
CROSS FADE EN
MIX
30
32
34
36
38

FIG. 2

SHAPING OF AUTOMATIC AUDIO CROSSFADE

BACKGROUND OF THE INVENTION

The present invention relates to audio mixers, and more particularly to the shaping of automatic audio crossfades to provide a more pleasingly aesthetic sound as a transition is made from one audio mix to another.

In audio production one commonly performed operation is a crossfade where a controlled smooth transition is made between one audio mix and another. On a manually controlled system an operator fades up a source being brought into the mix while fading out another source being removed. Due to the nature of sound the sources must be mixed in such a manner that both sources are down 6 dB from their full on settings midway through the mix. Mixing systems have been developed to automate this process, using addition rules for sound sources in the mixing algorithm. An automatic crossfade using the theoretical algorithm results in a transition that some listeners find too abrupt because at either end of the transition the level of the lower gain source is changing rapidly and is perceived as a cut rather than a fade. Human operators instinctively correct for this abruptness at the ends of the crossfade by modifying their manual motion. The perceived cut effect is exaggerated if the automatic control system runs on a sampling rather than continuous basis where large gain changes cannot be produced smoothly.

Therefore what is desired is an automatic audio crossfade process that modifies the theoretical crossfade algorithm to produce a smooth transition that is pleasing to a listener.

SUMMARY OF THE INVENTION

Accordingly the present invention provides shaping for an automatic audio crossfade by modifying a theoretical crossfade algorithm such that the rate of change of the level of the lower gain source at the limit of audibility is decreased. For theoretical crossfade the gain change per sample time increment is determined by taking the total gain change in dB, converting to a gain ratio and dividing by the total number of samples. This fraction of the total gain ratio is then converted back to dB and added to the original gain. Added to this logarithmic function is a correction to give an "S" shaping to the crossfade by adding another function, such as a cosine-based function, to the fraction completed term. The amount of the correction is determined with a table look-up, and results in the slope of the crossfade being decreased at the limit of audibility to produce an aesthetically pleasing transition sound.

The objects, advantages and other novel features of the present invention are apparent from the following detailed description when read in conjunction with the appended claims and attached drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a simplified block diagram view of an audio mixer architecture suitable for using the present invention.

FIG. 2 is a plan view of a control panel for an audio mixer implementing the current invention.

FIG. 3 is a graphic view of a crossfade as modified according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 an audio mixer 10 is shown having two audio input channels 12, 14 for receiving audio signals IN1, IN2 from two different audio sources (not shown). The outputs of the audio input channels 12, 14 are input to respective variable gain elements 16, 18, the outputs of which are in turn input to a summer 20. The output of the summer 20 is an audio mix output. The audio mix between the audio sources is controlled either manually from a control panel 22 or automatically by a microprocessor 24. A digital interface 26 has analog outputs coupled to the variable gain elements 16, 18 to provide a gain control signal to vary the gain of the signals input to the summer 20. The digital interface 26 performs digital to analog and analog to digital conversions as necessary to transfer information between the control panel 22 the microprocessor 24 and the gain elements 16, 18.

As shown in FIG. 2 the control panel 22 has individual gain control slides 30 for each audio input channel as well as master gain control slides 32 for each output audio channel. Also a crossfade slide 34 is shown together with a crossfade enable button 36. To perform a manual crossfade from a program audio mix to a preset audio mix that is stored in a preset register of the microprocessor 24 during set up, the crossfade enable button 36 is activated and the crossfade slide 34 is moved by an operator from one extreme position to another. This causes the audio mix to change from the program mix to the preset mix, i.e., decreasing the value of the gain control signal applied to one variable gain element 16 while increasing the value of the gain control signal applied to the other variable gain element 18. To perform this audio mix automatically a mix button 38 is pushed and the audio mix occurs over a specified transition time interval.

For the automatic audio mix the microprocessor 24 produces a control function that is not linear in dB versus time. The control function is logarithmically based to compensate for the non-additive mixing property of sound. When crossfading from one source to another of equal intensity the overall output level remains essentially constant. To produce the log function the gain change in dB is converted to a voltage ratio, multiplied by a transition complete fraction, and converted back to dB. The equation for this calculation takes one of two forms, depending upon whether the gain change between the program mix and the preset mix gains is positive or negative. For the positive gain change case:

$$G_{trans}=G_{prog}+G_{delta}$$

where:

$$G_{delta}=20*log\{(t/TOTAL)*10(G_{pres}-G_{prog})/20\}$$

For the negative gain change case:

$$G_{trans}=G_{pres}+G_{delta}$$

where G_{delta} is similar except t=t-TOTAL and $(G_{pres}-G_{prog})=(G_{prog}-G_{pres})$. To implement these basic equations the log and exponential functions may be accomplished with a table, with the exponential function being a simple look-up table and the log func-

tion using a binary search. Alternatively with a fast enough processor and/or math co-processor these basic equations may be equated directly. The shaping correction is added as a term to the exponential multiplier so that the scalar portion of the log function of delta gain becomes

$$k-S(k)$$

where $k=t/\text{TOTAL}$ or $(t-\text{TOTAL})/\text{TOTAL}$. The function $S(k)$ likewise may be accomplished using a table look-up that represents the desired shaping function, such as a cosine function, or may be computed directly with a fast processor and/or math co-processor. The computational period is a function of the sampling rate of the D/A converters of the digital interface 26, which for television applications could be once per field while for film applications it might be two to four times that rate, so long as the incremental changes are smooth to the listener.

The crossfade function is shown in FIG. 3 where the solid line represents the theoretical crossfade of the first set of equations without the shaping correction function. The dotted line shows the theoretical crossfade as modified by the shaping of the present invention. The significant factor is that the slope of the gain changes at the limit of audibility, which is generally in the vicinity of −30 dB, is decreased so that incremental changes are not of such a magnitude as to give the impression of a "snap-on" or "snap-off" of the lower gain audio source.

Thus the present invention provides shaping of the automatic audio crossfade by adding a shaping function to the theoretical crossfade logarithmic function to decrease the slope of the crossfade function at the limit of audibility.

What is claimed is:

1. A method of automatic audio crossfading between a first audio source and a second audio source over a specified time interval comprising the steps of:
   - computing a gain change value for each audio source as a function of a fractional part of the specified time interval that has been completed and of a difference in gain between the audio sources for a current time increment within the specified time interval using a modified theoretical crossfade function that has a gain level versus time slope at a limit of audibility that avoids apparent snap-on or snap-off of the audio source having a lower gain level at the beginning and end of the specified time interval;
   - adding the respective gain change values to current gains of the respective audio sources to produce new current gain values;
   - applying the new current gain values to the respective audio sources;
   - mixing the respective audio sources to produce an output audio mix; and
   - repeating the computing, adding, applying and mixing steps for subsequent current time increments until the specified time interval is completed.

2. An apparatus for performing an automatic audio crossfade between audio sources comprising:
   - means for receiving audio signals from a plurality of audio sources;
   - means for mixing selected ones of the audio signals to produce an audio mix output signal; and
   - means for controlling the mixing means so that an automatic crossfade from one audio source to another in the audio mix output signal follows a modified theoretical crossfade function that has a gain level versus time slope at a limit of audibility that avoids apparent snap-on or snap-off of the audio source having a lower gain level.

3. An apparatus as recited in claim 2 wherein the mixing means comprises:
   - means for programmably attenuating each audio signal from the receiving means to produce attenuated audio signals; and
   - means for combining the attenuated audio signals to produce the audio mix output signal.

4. An apparatus as recited in claim 3 wherein the controlling means comprises:
   - means for computing the modified theoretical crossfade function for each audio signal as a function of a specified time interval to complete the automatic audio crossfade plus a shape function and of a gain differential between audio signals to produce a separate gain control signal for each audio signal; and
   - means for interfacing between the computing means and the programmably attenuating means to apply the separate gain control signals to the audio signals to produce the attenuated audio signals.

5. A method as recited in claim 1 wherein the computing step comprises the steps of:
   - converting the difference in gain to a gain ratio;
   - adding a shape function to the fractional part to produce a modified fractional part;
   - multiplying the gain ratio by the modified fractional part to produce a proportional gain ratio; and
   - converting the proportional gain ratio to the gain change value.

* * * * *

US005177801A

United States Patent [19]

Shoda et al.

[11] **Patent Number: 5,177,801**

[45] **Date of Patent: Jan. 5, 1993**

[54] **CROSS FADER FOR EDITING AUDIO SIGNALS**

[75] Inventors: **Akihiko Shoda**, Tokyo; **Yoshihiro Murakami**, Kanagawa, both of Japan

[73] Assignee: **Sony Corporation**, Tokyo, Japan

[21] Appl. No.: **672,659**

[22] Filed: **Mar. 22, 1991**

[30] **Foreign Application Priority Data**

Mar. 28, 1990 [JP] Japan 2-80303

[51] **Int. Cl.**^{5} **H04B 1/00; H03G 3/00**

[52] **U.S. Cl.** **381/119**; 381/104; 381/109

[58] **Field of Search** .... 381/104, 109, 119; 84/625, 660, 464 R, 464 A

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Primary Examiner—James L. Dwyer
Assistant Examiner—Jack Chiang
Attorney, Agent, or Firm—Ronald P. Kananen

[57] **ABSTRACT**

A cross fader for editing audio signals has first and second bus lines, each including a plurality of channel signal lines and first and second plural selecting and indicating switches, each corresponding to the signal line of the first and second bus lines, for selecting the corresponding signal line responsive to the switching operation and for visually indicating the selected modes of the signal line. A fader mixes signals from the first and second selecting and indicating switches for outputting a mixed signal and for variably controlling the mixing ratio of the signals according to the movement of an operation knob. The first and second selecting and indicating switches are arranged so that said first and second switches are related with one end and the other end of the movement of the operation knob, respectively.

18 Claims, 3 Drawing Sheets

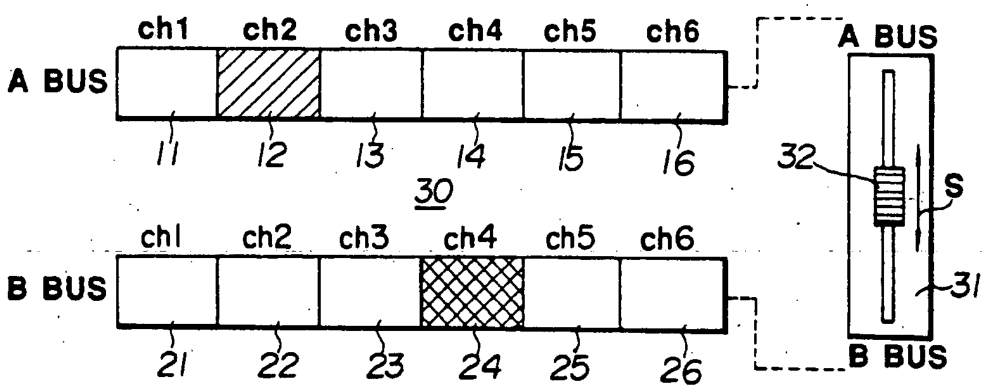

Fig 4

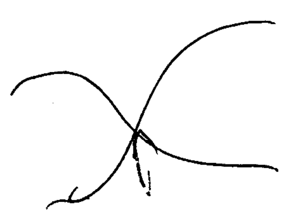

FIG. 1

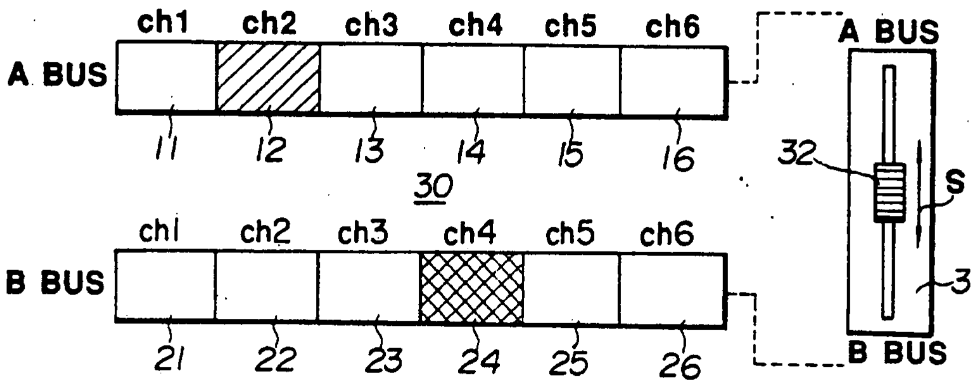

FIG. 1A

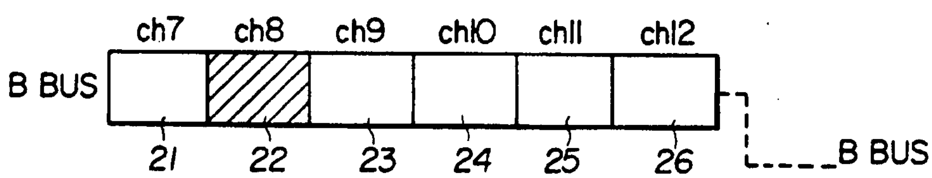

FIG. 1B

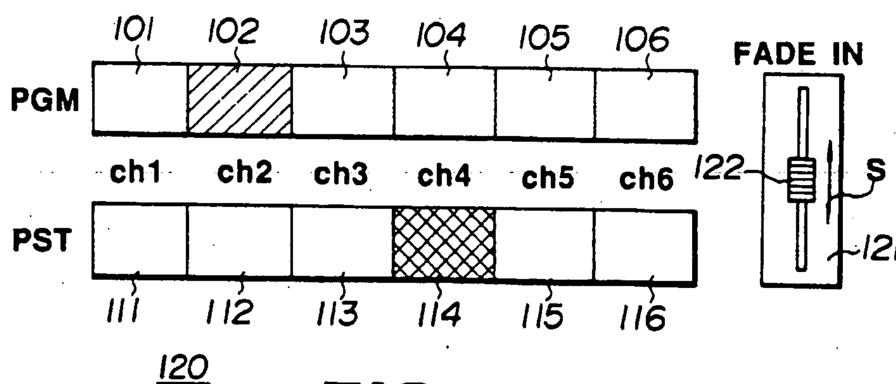

FIG. 3
PRIOR ART

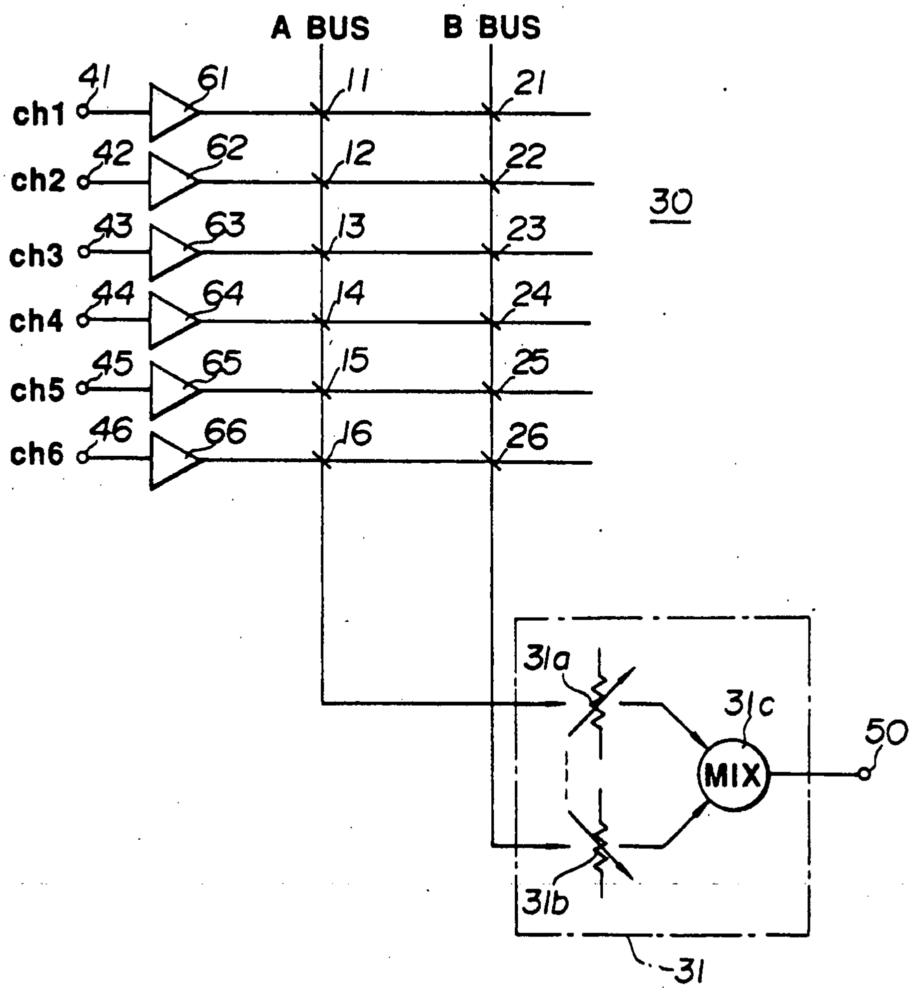
A BUS
B BUS
41
61
11
21
ch1
42
62
12
22
ch2
30
43
63
13
23
ch3
44
64
14
24
ch4
45
65
15
25
ch5
46
66
16
26
ch6
31a
31c
MIX
50
31b
31

FIG. 2

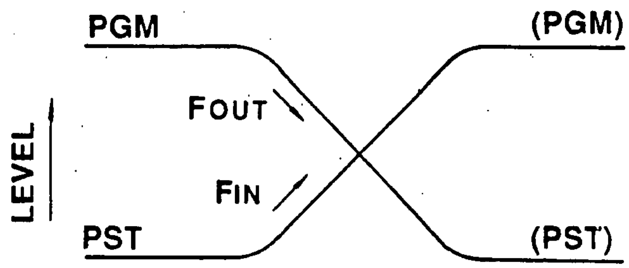

FIG. 4

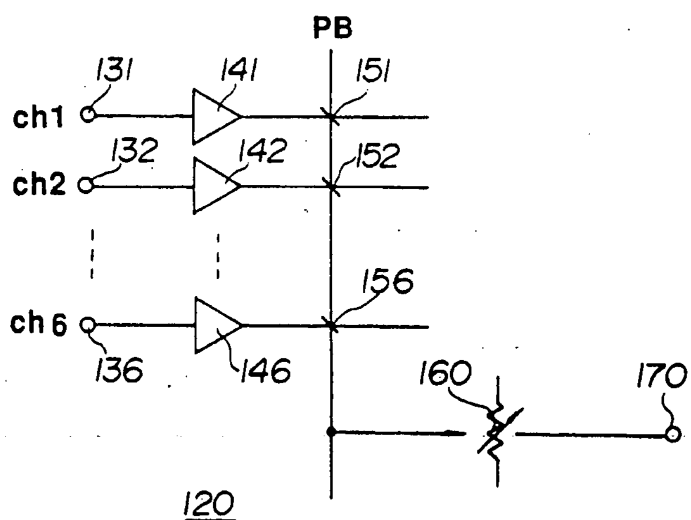

FIG. 5
PRIOR ART

CROSS FADER FOR EDITING AUDIO SIGNALS

BACKGROUND OF THE INVENTION

The present invention relates to an audio signal editing cross fader used for editing audio signals and the like.

There have been conventional cross faders used in a mixer for editing audio signals comprising a program (PGM) bus including signal lines of the audio signals of a plurality of channels and a preset (PST) bus including signal lines of the audio signals of a plurality of channels. A term "cross fader" used herein means an apparatus for adjusting (fading in and out the levels of signals so that, previous sound is superposed on and gradually changed to, subsequent sound before and after an editing point when the audio sounds and the like are edited. An audio signal before the editing point is a signal on the program (PGM) bus. An audio signal after the editing point is the signal on the preset (PST) bus.

For example, as shown in FIG. 3, selecting and indicating switches **101** through **106**, **111** through **116** which are connected to signal lines of a plurality of channels (for example, 6 channels ch1 through ch6) and a fader **121** which achieves, fade-in or fade-out, of audio signals by moving an operation knob **122** is a direction of an arrow S (i.e., a vertical direction) are disposed on a control panel of the conventional cross fader **120**.

That is, the selecting and indicating switches **101** through **106** are adapted to select a channel to be programmed by turning on, that is, a channel to be faded out before an editing point. The selecting and indicating switches **111** through **116** are adapted to select a channel to be preset by turning on, that is, a channel to be faded in after the editing point. Each of selecting and indicating switches **101** through **106**, **111** through **116** glows to indicate which channel is selected when it is turned on. As shown in FIG. 4, the fader **121** fades out the audio signal of a program (PGM) channel according to a curve F_{OUT} in FIG. 4 when the operation knob **122** is moved, for example, from the upper end to the lower end and fades in the audio signal of a preset channel according to a curve F_{IN} in FIG. 4 when the knob **122** is moved, for example, from the lower end to the upper end.

Referring now to FIG. 5, there is shown the schematic structure of a mixer using a usual master fader which performs no cross fading. In FIG. 5, audio signals of channels ch1 through ch6 are supplied to input terminals **131** through **136**, respectively. The signals are fed to selecting and indicating switches **151** through **156** via buffer amplifiers **141** through **146**, respectively. The switches **151** through **156** are connected with a program bus PB, which is in turn connected with a master fader **160**. Accordingly, when any one (or more) of the selecting and indicating switches **151** through **156** is turned on, the signal of the channel selected by turning on is fed to the master fader **160**, at which the level of the signal is adjusted and the level adjusted signal is outputted from an output terminal **170**.

In the above mentioned conventional cross fader **120**, positions of a program bus and a preset bus which are turned on are changed by the vertical movement of the operation knob **122**. This is, the indications of the selecting and indicating switches indicating which of the channels which are programmed and preset are changed depending upon the vertical movement of the operation knob **122**.

For example, when the channels ch2 and ch4 are in program and preset modes, respectively, both the selecting and indicating switch **102** corresponding to the programmed channel ch2 and the selecting and indicating switch **114** corresponding to the preset channel ch4 light. Movement of the knob **122** to the upper end causes the audio signals of the channels ch2 and ch4 to be faded out and in, respectively. At this time, since the signal of the channel ch2 which has been programmed is faded out, the channel ch2 is brought into a preset mode. Since the signal of the channel ch4 which has been preset is faded in, the channel ch4 is brought into a program mode (refer to FIG. 4). Accordingly, the selecting and indicating switch **102** which indicates a program mode of the channel ch2 fails to light while the selecting and indicating switch **112** which indicates a present mode of the channel ch2 lights. Simultaneously, the selecting and indicating switch which indicates a preset mode of the channel ch4 fails to light while the selecting and indicating switch **104** which indicates a program mode of the channel ch4 lights.

Such changes in program and preset modes are not so troublesome when, for example, video switcher is used since only one source is selected. However, channels to be switched are plural in a switcher which selects (mixes) a plurality of source (audio signals) like a mixer which processes audio signals. Accordingly, change in positions of lighting plural switches due to the above mentioned cross fading operation is very troublesome for an operator of the mixer. That is, since the program and preset buses are relevant to so-called assignment switches in an usual mixer and turning on (lighting) of the assignment switches change by the cross fader, the change in positions of lighting switches are troublesome. Movement of the operation knob of the cross fader in either direction causes a resultant signal to become a faded-in programmed signal. Therefore, the conventional cross fader is very troublesome for users which use a mixer including an usual master fader. The users who are inexperienced in operating such a cross fader may mistake channels which are in program or preset modes, resulting in errors of operation.

Therefore, the present invention was proposed under the above mentioned circumstances.

It is an object to provide a cross fader for editing audio signals which gives, good feeling of use and may reduce errors of operation.

SUMMARY OF THE INVENTION

In order to accomplish the above mentioned object, the present invention provides a cross fader for editing audio signals, comprising: first and second bus lines, each including a plurality of channel signal lines; first and second plural selecting and indicating switches, each corresponding to a signal line of the first and second bus lines, for selecting the corresponding signal line responsive to the switching operation and for visually indicating the selected modes of the signal line; and fader means which mixes signals from the first and second selecting and indicating switches for outputting a mixed signal and for variably controlling the mixing ratio of the signals according to the movement of an operation knob, said first and second selecting and indicating switches being arranged so that said first and second switches are related with one end and the other

end of the movement of the operation knob, respectively.

Visual indication of selected modes of the first and second selecting and indicating switches can be realized by using dual color glowing switches and the like which enable users to recognize the difference in selected modes by changing the glowing colors such as red and yellow.

In accordance with the present invention, program and preset modes of the selected channels can be easily recognized since the selected modes of bus lines are visually indicated and the direction of movement of an operation knob of the cross fader is related with the position of the arrangement of the first and second selecting and indicating switches.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1-1B is a schematic diagram showing the arrangement of alternate embodiments as shown respectively in FIGS. 1A and 1B of an audio signal editing cross fader of the present invention;

FIG. 2 is a circuit diagram showing the schematic structure of a circuit of the cross fader of the present embodiment;

FIG. 3 is a schematic diagram showing the arrangement of main parts of a conventional cross fader;

FIG. 4 is a graph for illustrating fade-in and fade-out operation performed by the cross fader; and

FIG. 5 is a schematic circuit diagram showing the structure of a mixer using a conventional master fader.

DESCRIIPTION OF THE PREFERRED EXBODIMENTS

Embodiments of the present invention will now be described with reference to the drawings.

Referring now to FIG. 1A, there is shown the arrangement of main components on a control panel of an embodiment of a cross fader 30 for editing audio signals of the present invention.

The cross-fader 30 of the present embodiment shown in FIG. 1A comprises an A bus which is a first bus line and a B bus which is a second bus line, each bus including a plurality of (for example, 6) channel signal lines to which audio signals ar supplied; a plurality of A bus selecting and lighting switches 11 through 16 which are first selecting and indicating switches and a plurality of B bus selecting and lighting switches 21 through 26 which are second selecting and indicating switches, one provided for each signal line of the bus lines of the A and B buses, for selecting one of the signal lines responsive to the switching operation and for visually indicating the selected mode (for example, indicating one of different glowing colors such as red and yellow); and a fader 31 for mixing the signals from the A and B bus selecting and glowing switches 11 through 16, 21 through 26 to output the mixed signals and for variably controlling the mixing ratio of the signals responsive to the movement of a knob 32, for example in a direction of an arrow S. The A bus selecting and glowing switches 11 through 16 are disposed so that they are related with one end to which the knob 32 of the fader 31 is moved and the B bus selecting and lighting switches 21 through 26 are disposed so that they are related with the other end to which the knob 32 is moved.

That is, the audio signals are on channels ch1 through ch6 of each of A and B buses in FIG. 1A. For example, the audio signal of the channel ch1 is supplied to the A and B bus selecting and lighting switches 11 and 21. The signal of the channel ch2 is supplied to the A and B bus selecting and glowing switches 12 and 22. The signal of the channel ch6 is supplied to the A and B bus selecting and glowing switches 16 and 26 similarly to the foregoing. The channels of the A bus may be different from those of the B bus. For example, the channels of the A bus may be channels ch1 through ch6 whereas the channels of the B bus may be channels ch7 through ch12. Each of A and B bus selecting and glowing switches comprises a dual color glowing switch which is capable of changing the glowing colors, for example, red and yellow. When it glows red, it indicates a program bus (that the channel is in a program mode). When it glows yellow, it indicates a preset bus (that the channel is in a preset mode). Accordingly, use of each A and B selecting and glowing switch in which a change in glowing colors makes it easy to recognize the difference in selection modes of program and present. It is, of course, that the glowing colors of the dual color glowing switch are not limited to only red and yellow and may be the other colors if the difference therebetween may be clearly recognized. However, the glowing colors of the switches should be unified corresponding to the selected mode, program or preset mode. The selecting and glowing switch may not be a dual color glowing switch, but a mono color glowing switch.

The A and B bus selecting and glowing switches 11 through 16, 21 through 26 are arranged so that both switches have a physically positional relation as shown by a dotted line in FIG. 1A. For example, as is exemplarily shown in FIG. 1A, if the fader 31 is disposed so that the operation knob 32 is vertically movable on the control panel of the cross-fader, the A bus selecting and glowing switches 11 through 16 are disposed in the upper side of the control panel so that they correspond to the upper end of the fader 31 while the B bus selecting and glowing switches 21 through 26 are disposed in the lower side of the control panel so that they correspond to the lower end of the fader 31. In this fader 31, the audio signal of the channel in which the preset mode is selected by any one of the A bus selecting and glowing switches 11 through 16 is faded in and the channel is brought into a program mode when the operation knob 32 is moved to the upper end and the audio signal of the channel in which a preset mode is selected by any one of the B bus selecting and glowing switches 21 through 26 is faded in and the channel is brought into a program mode when the operation knob 32 is moved to the lower end.

The fader is adapted to mix the signals, each from the A and B bus selecting and glowing switches and to output the mixed signal as described above. For example, in the case that the channel ch2 is selected by turning on the A bus selecting and glowing switch 12 and the channel ch4 is selected by turning on the B bus selecting and glowing switch 24, the channel ch2 is in a program mode and the switch 12 glows in red and the channel ch4 is in a preset mode and the switch 24 glows in yellow when the operation knob 32 of the fader 31 is positioned at the upper end thereof. Accordingly, when the operation knob 32 is moved from the upper end to the lower end, the signal of the channel 4 is faded in and the signal of the channel 2 is faded out. In association with this, the A bus selecting and glowing switch 12 changes to glow yellow indicative of a preset mode and the B bus selecting and glowing switch 24 changes to glow red indicative of a program mode.

The cross fader of the present embodiment comprises A and B bus selecting and glowing switches **11** through **16**. **21** through **26** which visually indicate the selected modes in. for example. red and yellow and a fader **31** which mixes the signals from the A and B bus selecting and glowing switches and variably controls the mixing ratio responsive of the movement of the operation knob **32**. The A and B bus selecting and glowing switches and the direction of the movement of the operation knob **32** of the fader **31** have a physically positional relation as described above. Accordingly, it can be easily recognized which mode the channels selected by the A and B bus selecting and glowing switches are in. Since the selected modes can be easily recognized in such a manner, the feeling of use is so excellent that even an inexperienced operator can reduce errors in operation.

Referring now to FIG. **2**, there is shown a schematic circuit structure of the cross fader **30** of the present embodiment. In FIG. **2**, the audio signals of the channels ch1 through ch6 are supplied to input terminals **41** through **46**, respectively. These signals are fed to the A and B bus selecting and glowing switches **11** through **16**. **21** through **26** via buffer amplifiers **61** through **66**. The A bus selecting and glowing switches **11** through **16** are connected with an A bus. The B bus selecting and glowing switches **21** through **26** are connected with a B bus. The A and B buses are connected with the fader **31**. The fader **31** comprises level adjusters **31***a* and **31***b* which are inversely interlocked with each other and are connected with the A and B buses, respectively and a mixer **31***c* for mixing the A bus signal with the B bus signal. Since the level adjuster **31***a* is inversely interlocked with the level adjuster **31***b*, the level adjuster **31***b* raises the level of the signal when the level adjuster **31***a* lowers the level of the signal. Accordingly, when any one (or more) of the each of selecting and glowing switches are turned on. the audio signals of the channels selected by the turning on are fed to the fader **31** and the levels of the signals are adjusted and the signals are mixed with each other and the mixed signal is outputted from an output terminal **50**. This makes it possible to use the A and B bus as a program bus of a mixer using a usual master fader. Accordingly, the cross fader of the present embodiment may be used as a master fader.

Another embodiment of the present invention in which the audio signals of the channels of the A bus are different from those of channels of the B bus is possible. as shown in FIG. **1B**. In this case. the channels ch1 through ch6 may be connected with the A bus whereas the channels ch7 through ch12 may be connected with the B bus. For example, the signals of the channels ch1 through ch6 are supplied to the A bus selecting and glowing switches **11** through **16** whereas the signals of the channels ch7 through ch12 are supplied to the B bus selecting and glowing switches **21** through **26**. In this embodiment of FIG. 1B, each of the A and B bus selecting and glowing switches also comprises a dual color glowing switch as is similar to the former embodiment of FIG. **1A** and is adapted to glow red and yellow indicative of program and present modes, respectively. Accordingly, use of the A and B bus selecting and glowing switches which change the glowing colors makes it possible for operation to easily recognize the difference in selected modes. program or preset modes.

Also in the present FIG. **1B** embodiment. the A and B bus selecting and glowing switches **11** through **16**, **21** through **26** and the fader **31** are disposed so that they have a physically positional relation with each other as is similar to the foregoing. For example. the A bus selecting and glowing switches are disposed on the upper side so that they correspond to the upper end of the fader **31**. The B selecting and glowing switches are disposed on the lower side so that they correspond to the lower end of the fader **31**.

Also in the fader of the present embodiment, when the operation knob **32** is moved to the upper end, the signal of the channel selected by one of the A bus selecting and glowing switches **11** through **16** is faded in. When the operation knob is moved to the lower end, the signal of the channel selected by one of the B bus selecting and glowing switches **21** through **26** is faded in. Accordingly, for example, in the case that the channel ch2 is selected by turning on the A bus selecting and glowing switch **12** and the channel ch10 is selected by turning on the B bus selecting and glowing switch **24**, when the operation knob **32** is positioned at the upper end, the A bus selecting and glowing switch **12** glows red and the channel ch2 is brought into a program mode, and the B bus selecting and glowing switch **24** glows yellow and the channel ch10 is brought into a present mode. When the operation knob **32** is moved to the lower end at this time, the signal of the channel ch10 is faded in and the A bus selecting and glowing switch **12** changes to glow yellow indicative of a preset mode and the signal of the channel ch2 is faded out and the B bus selecting and glowing switch **24** changes to glow red indicative of a program mode.

As is apparent from the foregoing. it is appreciated that which mode, program or preset mode the channel selected by the A or B bus selecting and glowing switch is in is easily recognized also in the cross fader of the present embodiment as mentioned above. Since the selected mode is easily recognized, the feeling of use is excellent and even in experienced operator can reduce errors in operation.

While preferred embodiments has been described, it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.

We claim:

1. A cross fader for editing audio signals. comprising:

first and second bus lines. each including a plurality of channel signal lines;

first and second plural selecting and indicating switches, each respectively corresponding to a respective signal line of the first and second bus lines, for selecting the corresponding signal line responsive to a switching operation and for visually indicating at a surface of a control console a selected mode of the signal lines; and

fader means for mixing signals from selected first and second selecting and indicating switches, when switched, for outputting a mixed signal and for variably controlling the mixing ratio of the respective selected signals according to the movement of an operation knob operable from a surface of said console, wherein said first and second selecting and indicating switches are arranged so that said first and second switches are respectively physically related on a surface of the console to one end and to the other end of the movement of the operation knob of said fader means. respectively;

wherein said first and second selecting and indicating switches comprise dual color glowing switches which change the glowing colors depending upon a selected mode thereof.

2. A cross fader for editing audio signals as defined in claim 1 in which the glowing colors are red and yellow.

3. A cross fader for editing audio as defined in claim 1 in which the selected mode includes a program mode in which the signal is to be faded out and a preset mode in which the signal is to be faded in.

4. A cross fader for editing audio signals as defined in claim 1 in which the channels of the first bus are different from the channels of the second bus.

5. A cross fader for editing audio signals, comprising:

first and second bus lines, each including a plurality of channel signal lines;

first and second plural selecting and indicating switches, each respectively corresponding to a respective signal line of the first and second bus lines, for selecting the corresponding signal line responsive to a switching operation and for visually indicating at a surface of a control console a selected mode of the signal lines; and

fader means for mixing signals from selected first and second selecting and indicating switches, when switched, for outputting a mixed signal and for variably controlling the mixing ratio of the respective selected signals according to the movement of an operation knob operable from a surface of said console, wherein said first and second selecting and indicating switches are arranged so that said first and second switches are respectively physically related on a surface of the console to one end and to the other end of the movement of the operation knob of said fader means, respectively;

wherein said first and second selecting and indicating switches are arranged in at least two lines in a parallel relationship with each other and said fader knob travels adjacent and transverse to said parallel lines.

6. A cross fader for editing audio signals, comprising:

a first bus line which includes a first plurality of channel signal lines;

a second bus line which includes a second plurality of channel signal lines;

first switch means, including a first plurality of selecting and indicating switches respectively connected to said first bus line, each of said first plurality of switches corresponding to a selected one of said first plurality of channel signal lines, for selecting a corresponding signal line from said first plurality of channel signal lines responsive to a switching operation and for visually indicating at a surface of a control console a selected mode of the selected one of the first plurality of signal lines;

second switch means, including a second plurality of selecting and indicating switches respectively connected to said second bus line, each of said second plurality of switches corresponding to a selected one of said second plurality of channel signal lines, for selecting a corresponding signal line from said second plurality of channel signal lines responsive to a switching operation and for visually indicating at said surface of said control console a selected mode of the selected one of the second plurality of signal lines;

fader means for mixing signal from the selected first and second channel signal lines via said first and second plurality of selecting and indicating switches for outputting a mixed signal representative thereof and for variably controlling the mixing ratio of the signals from the selected first and second channels, said fader means including an operation knob movable between a first position and a second position at said surface of said console;

said first and second selecting and indicating switches being physically arranged so that said first plurality of switches is physically positionally related to said first position and said second plurality of switches is physically positionally related to said second position of said operation knob;

wherein said first and second selecting and indicating switches comprise dual color glowing switches which change their glowing colors depending upon a selected mode thereof.

7. The cross fader as set forth in claim 6 wherein said first position of said operation knob indicates a first mode for a selected signal from said first plurality of channel signal lines and a second mode for a selected signal from said second plurality of channel signal lines, and said second position of said operation knob indicates a second mode for said selected signal from said first plurality of channel signal lines and a first mode for a selected signal from said second plurality of channel signal lines.

8. The cross fader as set forth in claim 6 wherein a selected mode includes a program mode in which the selected signal is to be faced in and a present mode in which the signal is to be faded out.

9. The cross fader as set forth in claim 7 where said first mode is a program mode and said second mode is a preset mode.

10. The cross fader as set forth in claim 7 wherein said first and said second selecting and indicating switches comprise dual color glowing switches which change their glowing colors depending upon whether a first or a second mode is selected.

11. The cross fader as set forth in claim 6 wherein the signals on said first plurality of channel signal lines are the same as the signals on said second plurality of channel signal lines.

12. The cross fader as set forth in claim 6 wherein the signals on said first plurality of channel signal lines are different from the signals on said second plurality of channel signal lines.

13. The cross fader as set forth in claim 6 wherein the first mode is a faded-in mode and said second mode is a faded-out mode.

14. A cross fader for editing audio signals, comprising:

a first bus line which includes a first plurality of channel signal lines;

a second bus line which includes a second plurality of channel signal lines;

first switch means, including a first plurality of selecting and indicating switches respectively connected to said first bus line, each of said first plurality of switches corresponding to a selected one of said first plurality of channel signal lines, for selecting a corresponding signal line from said first plurality of channel signal lines responsive to a switching operation and for visually indicating at a surface of a control console a selected mode of the selected one of the first plurality of signal lines;

second switch means, including a second plurality of selecting and indicating switches respectively connected to said second bus line, each of said second plurality of switches corresponding to a selected one of said second plurality of channel signal lines, for selecting a corresponding signal line from said

second plurality of channel signal lines responsive to a switching operation and for visually indicating at said surface of said control console a selected mode of the selected one of the second plurality of signal lines;

fader means for mixing signal from the selected first and second channel signal lines via said first and second plurality of selecting and indicating switches for outputting a mixed signal representative thereof and for variably controlling the mixing ratio of the signals from the selected first and second channels, said fader means including an operation knob movable between a first position and a second position at said surface of said console;

said first and second selecting and indicating switches being physically arranged so that said first plurality of switches is physically positionally related to said first position and said second plurality of switches is physically positionally related to said second position of said operation knob; and

further including a control panel, wherein said first plurality and said second plurality of said selecting and indicating switches are respectively arrayed on said control panel in first and second generally parallel lines and said operation knob travels adjacent and transverse to said parallel lines.

15. The cross fader as set forth in claim **14** wherein said first and said second positions for said operation knob are arrayed on said control panel at respective ends of said first and said second lines, so that said operation knob also physically indicates the selected mode for each line and approximately the mixing ratio of said signals.

16. The cross fader as set forth in claim **15** wherein said first and said second parallel lines of said switches are about horizontal while a path for movement of said operation knob between said first and said second positions is approximately vertical.

17. The cross fader as set forth in claim **6** wherein said fader includes a first level adjuster connected to receive selected signals from said first plurality of channel signal lines and a second level adjuster connected to receive selected signals from said second plurality of channel signal lines, said first and said second level adjusters being inversely interlocked with said operation knob so that when said first level adjuster raises the level of the selected signal from the first plurality of channel signal lines, the second level adjuster lowers the level of the selected signal from the second plurality of channel signal lines.

18. A cross fader for editing audio signals, comprising:

a control panel;

a first plurality of selecting and indicating switches arrayed in a first row on said control panel for selecting a corresponding signal line of a first plurality of signal lines on a first bus line and visually indicating the selected mode of the selected first signal line;

a second plurality of selecting and indicating switches arrayed in a second row on said control panel for selecting a corresponding signal line of a second plurality of signal lines on a second bus line and visually indicating the selected mode of the selected second signal line, said first and second rows being located about parallel and about horizontal on said control panel; and

a fader having an operation knob movable between a first position at about the end of the first row and a second position at about the end of the second row for mixing signals from selected first and second selecting and indicating switches, said first position indicating a first selected mode and said second position indicating a second selected mode wherein said first and second selecting and indicating switches comprise dual color growing switches which change the glowing colors depending upon a selecting mode thereof.

* * * * *

United States Patent [19]

Blackington

[11] **4,376,566**

[45] **Mar. 15, 1983**

[54] **FIBER OPTIC SWITCHING METHOD AND APPARATUS WITH FLEXIBLE SHUTTER**

[75] Inventor: **Paul A. Blackington**, Vandling, Pa.

[73] Assignee: **Sheltered Workshop for the Disabled, Inc.**, Binghamton, N.Y.

[21] Appl. No.: **323,531**

[22] Filed: **Nov. 20, 1981**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 126,178, Mar. 3, 1980, abandoned.

[51] Int. Cl.^{3} **G02B 5/14**

[52] U.S. Cl. **350/96.2**; 250/227

[58] **Field of Search** 350/96.2, 96.15; 250/227

[56] **References Cited**

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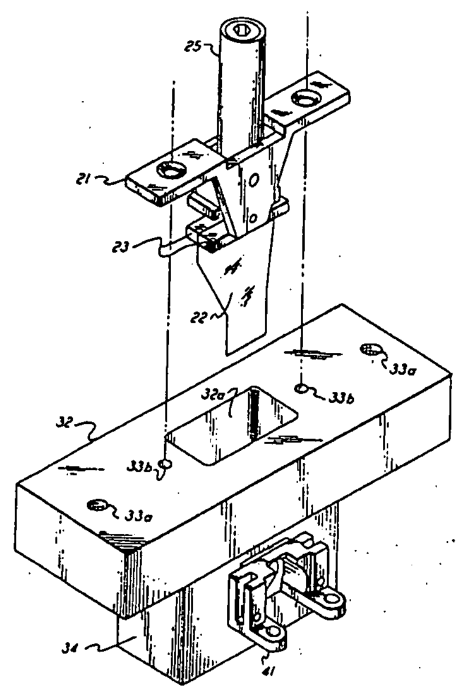
Primary Examiner—David K. Moore
Attorney, Agent, or Firm—Richard G. Stephens

[57] **ABSTRACT**

An extremely thin shutter is moved into and out of the space between closely-spaced ends of a pair of axially and angularly aligned optic fibers to prevent or establish transmission of light between the fibers. In one embodiment a cantilever shutter is rotated between two positions. In another embodiment a taut band-like shutter having an aperture is translated between two positions.

12 Claims, 14 Drawing Figures

Slide
Between
axial aligned



C shape

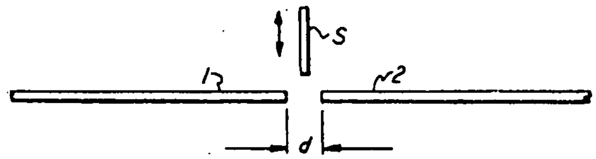


FIG. 1

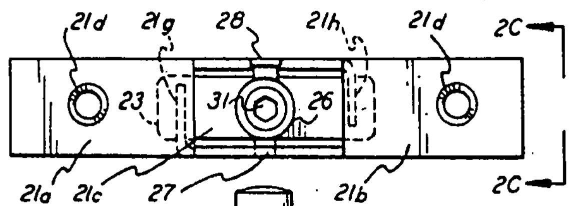


FIG. 2a

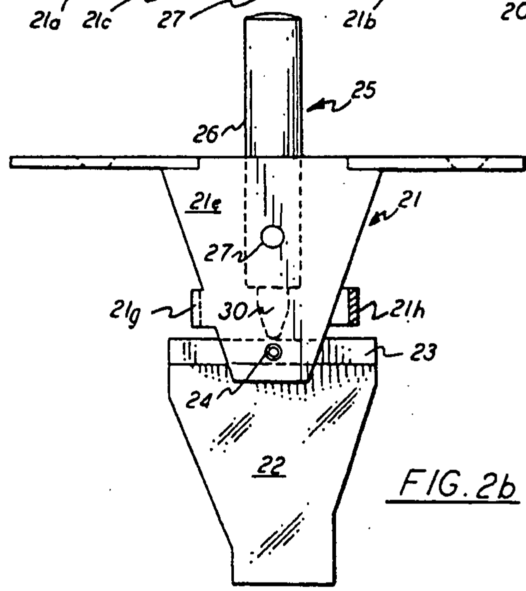


FIG. 2b

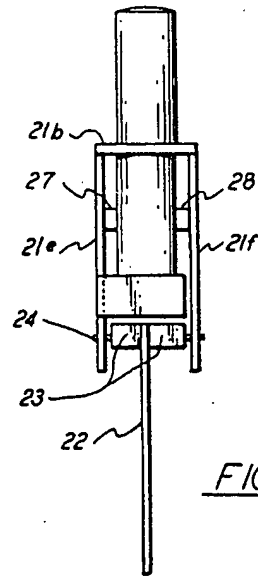


FIG. 2c

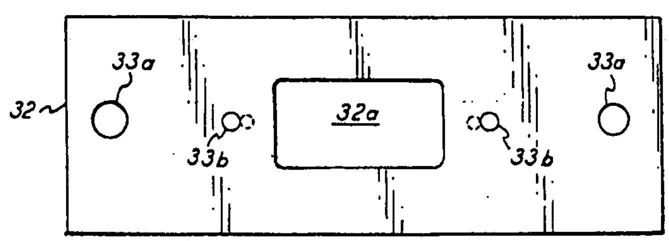


FIG. 3a

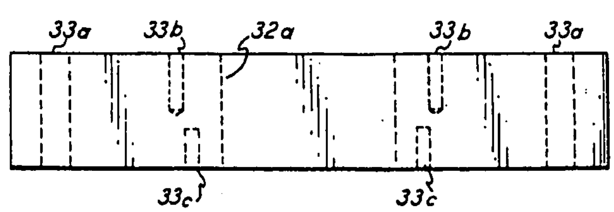


FIG. 3b

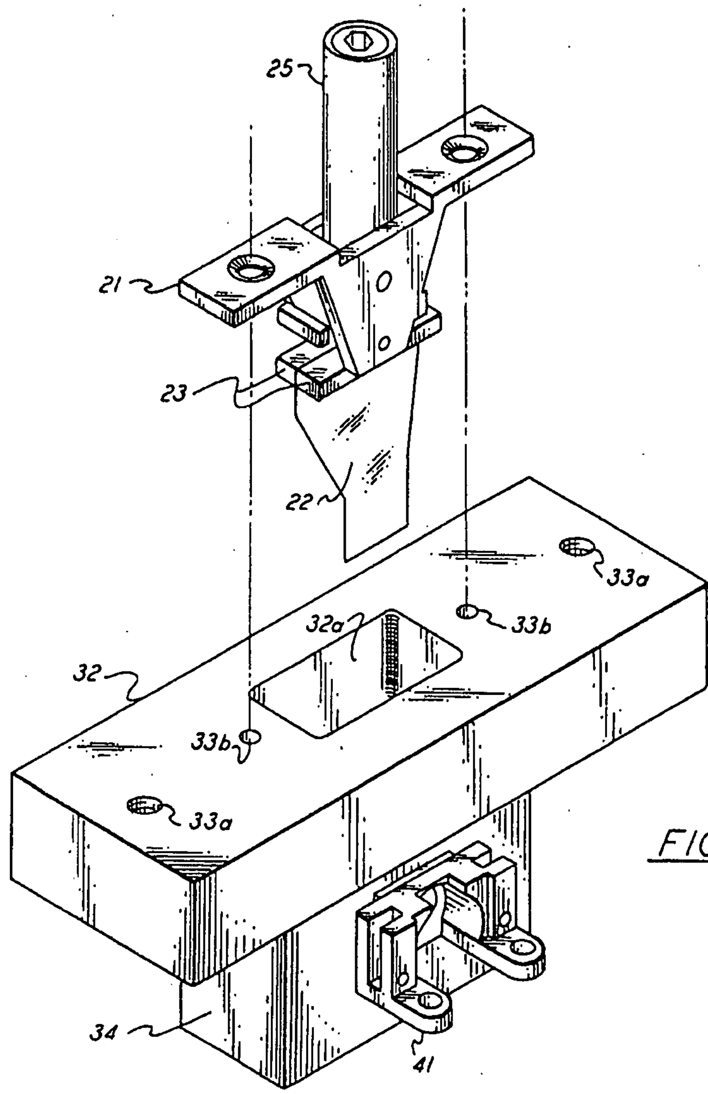


FIG. 5

FIG. 4a

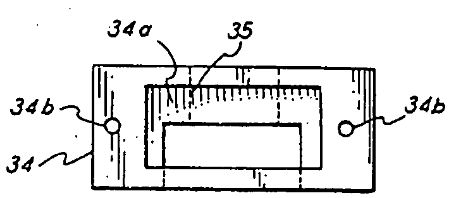
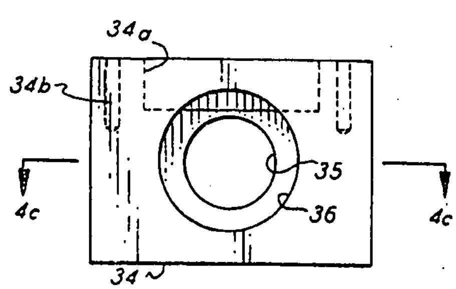


FIG. 4b



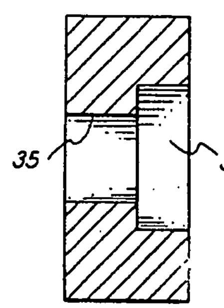


FIG. 4c

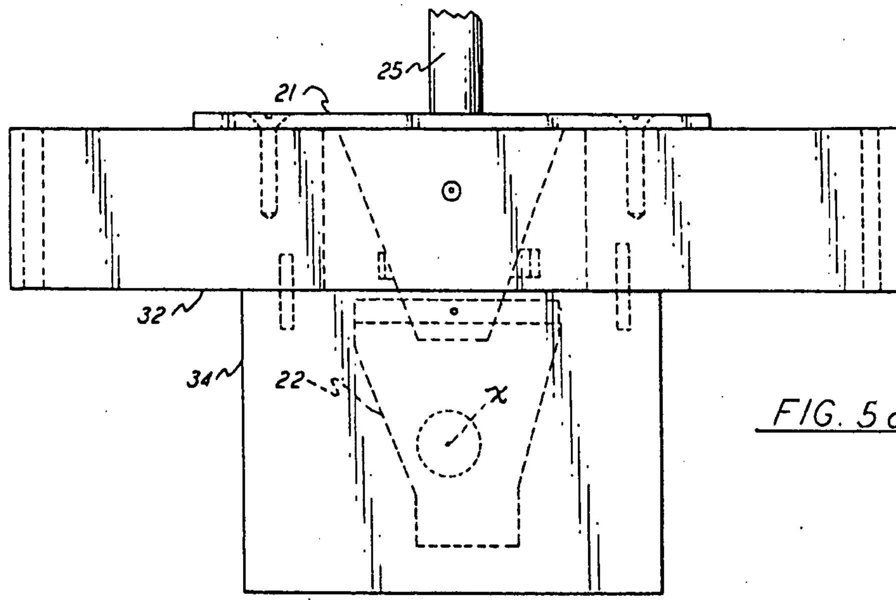


FIG. 5a

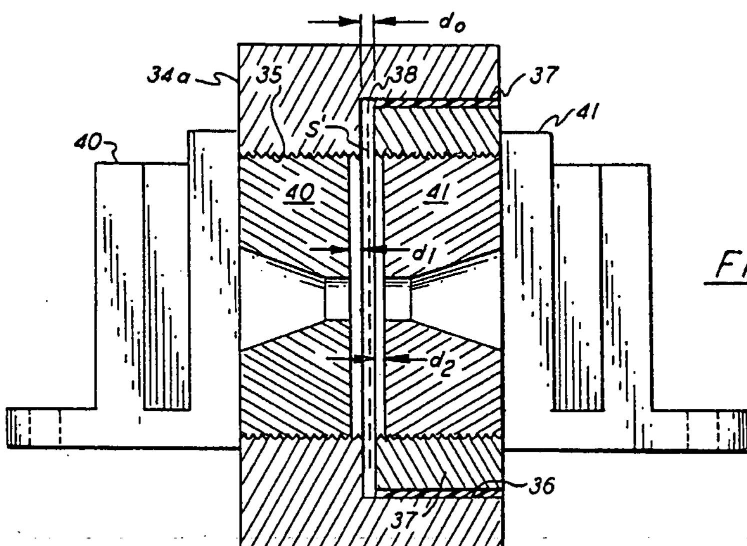
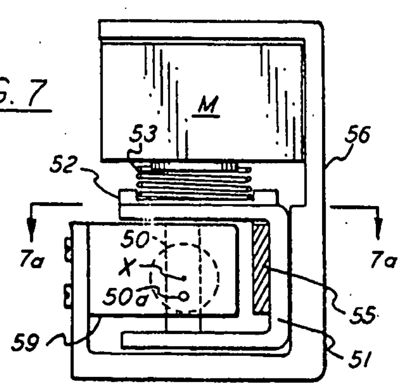


FIG. 6

FIG. 7



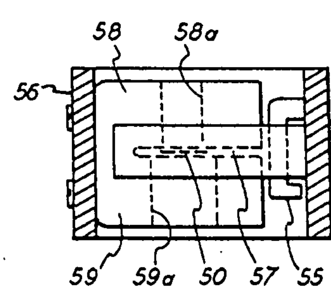


FIG. 7a

FIBER OPTIC SWITCHING METHOD AND APPARATUS WITH FLEXIBLE SHUTTER

This application is a continuation-in-part of my prior copending Application Ser. No. 126,178 filed Mar. 3, 1980 and now abandoned. This invention relates to fiber optic switches, i.e. devices for selectively allowing and interrupting passage of light between a pair of ends of two optic fibers.

OBJECTS OF THE INVENTION

It is desirable in most applications that a fiber optic switch pass light out an end of one fiber into an end of another fiber with minimum light loss when the switch is in its conducting condition, or "on", and further desirable that passage of light be interrupted or prevented as completely as possible when the switch is in its nonconducting condition, or "off". One general object of the invention is to provide light switching method and apparatus having both low loss during the "on" condition and low leakage during the "off" condition.

Various switches have been proposed wherein switching of light is done by physically moving the end of one fiber relative to the stationary end of the other fiber, flexing the first fiber to the extent necessary. To operate with low loss in their "on" condition, such switches must incorporate very precise mechanisms which can faithfully and repeatedly re-position the movable fiber end relative to the fixed fiber end with very small axial and angular mis-alignments. Providing such mechanisms presents difficulties. If fixed stops are provided to determine movement of the movable fiber end, such stops must be cut with great precision, and the wear of such stops after long usage tends to increase light loss. If adjustable stops are used instead, manufacturing tolerances need not be as critical, but adjustment tends to be tedious and time-consuming, and it undesirably requires the use of laboratory equipment. Wear of adjustable stops also tends to cause light loss. One object of the present invention is to overcome such problems which occur by moving a fiber end to accomplish switching. Thus one object of the present invention is to provide improved method and apparatus for switching light between two fiber ends wherein both fiber ends are held stationary. Another object of the invention is to provide light switching apparatus in which light loss during the "on" condition is not dependent upon any mechanism moving to an extremely precise position, so that any of a wide variety of known switch-actuator mechanisms having limited positioning precision may be used.

The broad principle of having both fiber ends stationary is not per se new, and a light switching device having that feature is shown in U.S. Pat. No. 4,023,887 (Speers). In the device suggested by Speers light conduction from the input fiber to the output fiber is established by rotating a disc carrying a short section of light-transmissive fiber, to interpose the short section in between the input fiber end and the output fiber end. While such an arrangement may be useful for some applications, it tends to be unsatisfactory if very low loss is required, principally because two light interfaces are required. Losses occur as light exits from the input fiber end into the short section, and further losses occur as light passes from the short section into the output fiber end. Further small losses can occur within the short section. Wear or play in the bearings which support the disc can cause axial and angular alignments which also cause loss. Another object of the present invention is to provide improved light switching method and apparatus for switching light between two stationary fiber ends wherein only a single light interface exists between the fiber ends during the "on" condition.

In accordance with one form of the present invention, an opaque shutter formed from very thin sheet material is arranged to swing between two alternate positions, in one of which a portion of the shutter lies between the two fiber ends, preventing passage of light, and in the other of which no portion of the shutter lies between the two fiber ends, so that light may pass from the input fiber to the output fiber. Forming the shutter of extremely thin opaque sheet material allows the two fiber ends to be mounted with a very small separation between them, which is extremely important in order to minimize light loss, but it makes the shutter very flexible, potentially making it extremely difficult to insert and remove a shutter portion from a space between the two fiber ends without having the shutter either abrade the end face of a fiber or jam against a fiber instead of entering between the two fiber ends. In accordance with a further feature of one embodiment of the invention, the fiber ends are fixed in a block which is provided with a track or slot in which portions of the flexible shutter may slide and be guided to avoid having the shutter strike either fiber end.

Another object of the invention is to provide light-switching apparatus which is simple and economical to construct, and capable of long use.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts, which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a diagram useful in understanding some basic principles of the invention.

FIGS. 2*a*, 2*b* and 2*c* are top, side elevation and end views of an exemplary shutter-rotating mechanism used with one embodiment of the invention.

FIGS. 3*a* and 3*b* are top and side elevation views of a mounting block portion of the same embodiment of the invention.

FIGS. 4*a*, 4*b* and 4*c* are top, side elevation, and cross-section views of a shutter cavity portion of the same embodiment of the invention.

FIG. 5 is an exploded isometric view illustrating how the apparatus of FIGS. 2*a*-2*c*, 3*a*, 3*b* and 4*a*-4*c* may be assembled, and FIG. 5*a* is a side view of the assembled apparatus.

FIG. 6 is a greatly enlarged view of portions of the shutter cavity showing a pair of conventional fiber optic connections installed therein.

FIG. 7 is a side elevation view of one alternative embodiment of the invention.

FIG. 7*a* is a section view taken at lines 7*a*—7*a* in FIG. 7.

Referring to FIG. 1 a pair of cylindrical optical fibers 1, 2 which may be plastic or glass are shown fixedly located relative to each other with a small separation

distance d between their ends. The fibers are assumed to be axially and angularly aligned with each other Light exits from the end of fiber 1 in a cone-shaped pattern having a spread dependent upon the numerical aperture of the fibers. As distance d is increased, decreasing amounts of the conical pattern of light are intercepted by fiber 2, causing greater light loss during the "on" condition when shutter S is not interposed between the ends of the fibers. Thus for minimum light loss during the "on" condition the fiber ends should be very close together, ideally touching each other. However, unless an appreciable separation exists between the fiber ends, there is not enough room to insert shutter S between the fiber ends in order to prevent light transmission when that is desired. In numerous applications it is desirable to use optical fibers of quite small diameters, such as diameters of 2 mils to 56 mils (0.0508 mm. to 1.422 mm.), for example. The smaller the diameter of the fibers, the greater the light loss which results from a given separation distance d. In accordance with the invention, a very small separation distance (e.g. 3 mils or 0.076 mm.) is provided between the fiber ends to minimize light loss during the "on" condition, and a very thin opaque shutter is moved in and out of the space between the fiber ends. The shutter preferably comprises a piece of steel sheet having a thickness of about 1 mil (0.0254 mm.), though brass or beryllium copper sheet could instead be used. Metal sheet is preferred because of its resistance to wear. Metal sheet having such a thickness tends to be quite flexible, potentially making it quite difficult mechanically to insert and remove a piece of such sheet into and from the space between fiber ends having such a small separation without having the sheet either abrade a polished fiber end or jam against the side of a fiber. In a form of the invention illustrated in FIGS. 2-6, a track is provided to guide a thin cantilever-mounted shutter as it is rotated in and out of the space between the fiber ends, and the fiber ends are slightly recessed from the space in which the track allows the shutter to move, preventing the flexible shutter from engaging either fiber end. In another embodiment, though the thin shutter is itself flexible, opposite edges of the shutter are gripped to hold it taut as it is moved to insert or remove an aperture in the shutter from the space between the fiber ends.

In FIGS. 2a, 2b and 2c one exemplary shutter pivoting mechanism is shown as comprising a frame 21 having upper plate portions 21a and 21b, an opening 21c and two mounting holes 21d, 21d, and a pair of side legs 21e, 21f depending from the upper plate portions to form a generally U-shaped frame. The thin membrane shutter 22 is sandwiched between and cemented to a pair of blocks 23, 23 to form a shutter mount. Pin 24 rotatably passes through holes through blocks 23, 23 and the shutter, and the ends of pin 24 are secured in respective holes in legs 21e and 21f. Actuating arm 25 comprises a hollow cylinder 26 which is pivotally mounted between side legs 21e, 21f on stub shafts 27, 28. Cylinder 26 slidably carries a plunger 30, and a coil spring (not shown) inside cylinder 26 urges the rounded end of plunger 30 against the top surface of the shutter mount. A set screw 31 in the upper end of cylinder 26 allows the spring pressure on plunger 30 to be adjusted. The mechanism is shown in FIGS. 2a, 2b and 2c in an unstable centered position in which the force exerted on the shutter mount is directed precisely toward the axis of pin 24. If the actuating arm is pivoted in one direction or another from that centered position, it will be apparent that the plunger force will be applied to one side or another of pin 24, causing rotation of the shutter-mount and shutter membrane about the axis of pin 24, until an upper edge of the shutter mount strikes stop tab portion 21g of leg 21e or stop tab portion 21h of leg 21f. Thus movement of actuating arm 25 in either direction through the centered condition shown snaps the shutter from one predetermined angular or pivotal position to another predetermined angular or pivotal position. The actuating arm will be rotated by the spring force until cylinder 26 strikes one edge or another of opening 21c. It is to be clearly understood that the particular shutter pivoting mechanism shown in FIGS. 2a-2c is exemplary only. A wide variety of mechanisms are known for pivoting electrical switch blades between two angular positions, and many of them can be modified to similarly pivot a thin shutter without the exercise of invention.

The shutter 22 comprises steel sheet of 1 mil (0.0254 mm.) thickness, and having that thickness it tends to be somewhat flexible. It is shown mounted in cantilever fashion, i.e. gripped only along one edge.

In FIGS. 3a and 3b a mounting block is shown as comprising a rectangular block 32 preferably formed of aluminum, having a central, rectangular hole or through-passage 32a. A pair of threaded holes 33a, 33a allow block 32 to be affixed to a standard electrical switch plate (not shown). A pair of threaded holes 33b, 33b allow frame 21 of the shutter-pivoting assembly to be affixed to block 32 via holes 21d, 21d (FIG. 2a). A pair of holes 33c, 33c receive pins (not shown in FIGS. 3a, 3b) which serve to locate a switch cavity block on mounting block 32.

The switch cavity block 34 is shown in FIGS. 4a, 4b and 4c as a generally-rectangular block, also preferably formed of aluminum, having an upper rectangular recess 34a. Holes 34b, 34b in block 34 receive pins (not shown) which also seat in holes 33c, 33c (FIG. 3b), so that recess 34a of block 34 registers with the similar size opening 32a through mounting block 32. A first cylindrical threaded bore 35 extending partway through block 35 is concentric with and communicates with a larger unthreaded cylindrical bore 36 which extends the rest of the way through block 34. Bore 36 has a diameter such that it intersects rectangular recess 34a. A conventional fiber optic connector 40 (FIG. 6) is threaded into bore 35 and cemented in place, and another conventional connector 41 is installed in a bore 36 using a cylindrical bushing 37 (FIG. 6) in a manner to be described. As is evident from FIGS. 5 and 5a, the shutter pivoting mechanism is lowered to seat atop mounting block 32, with the thin shutter 22 being lowered through opening 32 to reside within switch cavity block 34. The shutter 22 is again shown in an unstable centered condition in FIG. 5a. It will be understood that in one stable position the shutter completely covers the fiber optical axis (shown at x in FIG. 5a), and that in its other stable position it does not.

FIG. 6 is an enlarged view looking down into recess 34a of block 34, with a cylindrical bushing 37 shown cemented in bore 36. Bushing 37 has a threaded central bore 37a in which a conventional optic fiber connector 41 is threaded and cemented. A narrow gap space 38 approximately 2 mils (0.051 mm.) in width shown greatly exaggerated in FIG. 5 exists between one side of bushing 37 and the end of bore 36, providing a track along which thin membrane shutter 22 may move. The path along which shutter 22 moves is shown by dashed

line S' in FIG. 6. The left (in FIG. 6) edge or face of bushing **37** is spaced 2 mils (0.051 mm.) from the end of bore **36** by temporarily placing 2 mil shim stock (not shown) between those parts while the cement which affixes the bushing in bore **36** hardens. A cylindrical rod (not shown) is also extended through the two connectors while the cement hardens, to insure that the connectors will eventually be aligned axially and angularly. If gap **38** has a width of 2 mils (0.051 mm.) and shutter **22** has a thickness of 1 mil (0.0254 mm.), it will be apparent that shutter **22** theoretically could pivot within the gap with a half-mil (0.013 mm.) clearance on each side, if the shutter were perfectly flat and rigid. In practice, portions of the shutter slide against the end of bore **36** and the face of bushing **37**, but those surfaces greatly limit the axial positions which any portions of the shutter may take. In order to prevent any portion of the shutter from rubbing on a fiber end, each fiber optic connector is arranged to locate the end of its respective fiber a very small distance (e.g. 0.0005 inch, or 0.013 mm.) from an edge of the gap. Thus if gap **38** has an axial width of 2 mils (0.051 mm.), the polished ends of the two fibers may be an axial distance of 3 mils (0.076 mm.) from each other. In FIG. 6 the polished fiber ends are shown located distances d_1 and d_2, respectively, from the gap **38** of width d_o. Using such a fiber end separation, with fibers 5 mils (0.127 mm.) in diameter a light loss of about 6 db. was achieved, and with fibers 56 mils (1.42 mm.) in diameter, a loss of about 0.1 db. was obtained. Even if shutter **22** comprises such a thin steel sheet and is therefore flexible, it can move back and forth in the track without striking the end of either optical fiber, the bottom edge of bore **36** and the face of bushing **37** spaced slightly therefrom acting as guide surfaces against which the shutter may slide.

While the shutter moving mechanism has been shown as comprising a toggle-type, manually operated device which rotates a shutter, it is within the scope of the invention to provide switches wherein shutter motion is momentary rather than toggled, switches wherein shutter motion is provided by electrically, as by means of electromagnetic actuators, and switches in which a thin shutter is translated rather than rotated.

In another embodiment of light switch illustrated in FIGS. 7 and 7*a*, an extremely thin opaque shutter comprises a strip or band of metal sheet **50** held at its opposite ends by legs of a U-shaped member **51** which maintains the band taut. The band is generally opaque but includes a hole **50***a*. A ferromagnetic piece **52** affixed to the U-shaped member is pulled upwardly against the force of compression spring **53** when an electromagnet M is energized, locating the aperture in band **50** concentric with a pair of fiber ends, the axes of which are shown at x in FIG. 7*a*. Upon de-energization of the electromagnet, the U-shaped member and band are returned to the position shown, so that the band prevents transmission of light between the fiber ends. A tab **55** on frame **56** guides upward and downward movement of the U-shaped element. The band **50** rides in a thin slot **57** between a pair of block members **58**, **59** carried on frame **56**. Block member **58** includes a threaded opening **58***a*, and block member **59** includes an unthreaded bore **59***a*. A pair of fiber optic connectors (not shown) are mounted in bores **58***a* and **59***a* in the same manner as was described above in connection with FIG. 6.

While metal sheet is presently preferred as shutter material, it is believed that various plastic sheets may be substituted to provide equivalent operation.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained, and since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus for selectively establishing and preventing light transmission between first and second optical fibers, comprising, in combination: a support member having first and second recesses adapted to receive respective optic fiber connectors to fixedly space the ends of said fibers in axial and angular alignment with each other and with an air space between the ends of said fibers; an opaque flexible planar shutter having a thickness less than the width of said air space; means for moving said shutter between a first position in which a portion of said shutter completely intersects said air space between the ends of said fibers to prevent light transmission between said ends and a second position in which no portion of said shutter is interposed in said air space; and means for constraining movement of said portion of said shutter to a plane substantially perpendicular to the axes of said fibers.

2. Apparatus according to claim **1** wherein the width of said space is less then the diameter of said optic fibers.

3. Apparatus according to claim **1** wherein said means for constraining movement comprises a pair of surfaces on said support member limiting axial movement of said flexible planar shutter.

4. Apparatus according to claim **1** wherein said shutter comprises a thin piece of metal sheet.

5. Apparatus according to claim **1** wherein said means for moving comprises means for pivoting said shutter about a predetermined axis parallel to the axes of said ends of said fibers.

6. Apparatus according to claim **1** wherein said means for moving comprises means for translating said shutter.

7. Apparatus according to claim **1** wherein said shutter comprises a thin piece of sheet attached at one edge to said means for moving.

8. Apparatus according to claim **1** wherein said shutter comprises a thin piece of flexible sheet and said apparatus comprises means engaging opposite sides of said piece of sheet to maintain said piece taut.

9. Apparatus according to claim **1** wherein said shutter has a thickness less than 0.005 inch (0.127 mm.).

10. Apparatus according to claim **1** wherein said means for moving comprises a manually-operable member operable to toggle said shutter between said first and second positions.

11. Apparatus according to claim **1** wherein said means for moving comprises an electromagnet.

12. Apparatus according to claim **3** wherein said block member spaces apart said optic fiber connectors at a distance such that said surfaces are in between said ends of said fibers.

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